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Materials for the Construction of Photographic Processing Apparatus

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MATERIALS FOR THE CONSTRUCTION OF PHOTOGRAPHIC PROCESSING APPARATUS

When a material is selected for the construction of any particular piece of photographic processing apparatus, several factors should be considered, namely:

1. The resistivity of the material to the most corrosive liquid with which it will come in contact. For example, a galvanized tank, while fairly satisfactory for washing purposes, is very rapidly corroded and therefore is unsuitable for use with fixing baths.
2. The effect of the material on the photographic properties of the solution. For instance, a developer solution in a brass tank may appear visibly unchanged, but on being tested it may fog emulsions badly, due to the copper salts dissolved from the brass.
3. The time during which the solution will be in contact with the material. If a developer is stored in a japanned tank, the japan will ultimately soften and peel off.
4. The cost of the material.
5. The adaptability of the material for construction purposes. Glass, for example, is entirely unsuitable for large tanks because of its fragility and the difficulty of annealing.

There are three general classes of materials suitable for the construction of photographic apparatus intended for use as containers for or to be immersed in photographic solutions, namely: metallic materials, coated metals, and nonmetallic materials. These may be subclassed as follows:

A—Metallic materials: Unplated, plated, and clad metals; alloys.

B—Coated metals: Enameled steel, glass enameled steel, asphalt-coated metals, and lacquered metals.

C—Nonmetallic materials: Glass, impregnated fibrous materials, artificial resins alone or reinforced with fibrous matter or fabric, wood, paraffined wood, resin bonded plywood, porcelain and glazed earthenware, rubber, rubber composition, carbon and graphite compositions, and thermoplastic-cellulose ester and ether materials, slate, and Alberene stone.

METALLIC MATERIALS

No metal or alloy has yet been found which will resist corrosion completely in all photographic solutions; it is, therefore, necessary to restrict their use to specific purposes. Metallic materials, however, possess such desirable properties as ductility, nonfragility, and general workability, which suit them to the manufacture of small tanks, racks, film hangers, clips, and reels, etc.

In considering the suitability of a particular metal for construction purposes, it is very important to know whether the article will be built of a single metal or of two or more metals. In the former case only the corrosive effect of the solution itself need be considered; in the latter case an electrical current flows between different metals, and its effect must be considered in addition to the chemical action.

In testing the resistivity of various metallic materials to chemical action, it is necessary, therefore, to observe the effects obtained under two sets of conditions, (1) those in which only a single metal or alloy is involved, and (2) those in which two or more metals or alloys are in contact with each other and also with the photographic solutions.

The Resistivity of Single Metals in Photographic Solutions

An extended series of tests has been carried out to determine the resistivity of a large number of metals and alloys to common photographic solutions. The details of the tests on many of the materials given in the following list are recorded in a paper by two of the present authors.[1]

Metals: Aluminum, Copper, Iron, Lead, Nickel, Silver, Tantalum, Tin, Zinc.

Plated Metals: Galvanized iron, Tinned iron, Lead-coated iron, Chromium, Silver, and Cadmium-plated brass.

Alloys: Duralumin (aluminum-magnesium-copper), Duriron (iron-silicon, in cast form only), Hastelloy (various nickel alloys with molybdenum, iron, and chromium or other elements), Illium G and R (chromium-molybdenum-iron-nickel), Inconel (chromium-iron-nickel), Monel (nickel-copper alloy), Nichrome (nickel-chromium-iron), Nickel Silver (copper-zinc-nickel-iron), Phosphor Bronze (copper-tin-phosphorus), Solder (both high and low tin content), Stainless Steels

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[1] An extensive and useful list of various metals and alloys including wrought and cast stainless steels together with their standard types and designations, composition range, forms available, recommended methods of fabrication, manufacturers of the materials in the United States, and other data are given in Chem. & Met. Eng. *49*: (1942) pp. 105-128.

(18% chromium-8% nickel with varying carbon, columbium, molybdenum, titanium, selenium, and silicon content),[2] and Type Metal (lead-tin-antimony).

The Resistivity of Two or More Metals in Metallic Contact Toward Photographic Solutions

When two different metals are placed in contact and immersed in a solution, an electrolytic cell is formed which causes more or less rapid disintegration of one of the metals. This electrical action may occur in several ways; with plated metals, when some of the plating wears off; with soldered metals, between the solder and the metal; and with alloys, between tiny crystals of the various metals which compose the alloy and between portions which have received different mechanical or heat treatment.

In making metal containers for photographic solutions, it is often necessary to use a second metal or alloy in the form of solder, to render the joints or seams free from leaks. Also in the construction of pipe lines for transporting solutions, it frequently is not possible to use faucets or fittings of the same material as the pipe line. An example of the trouble which arises from metallic contact in a solution follows:

In the course of a series of tests on metal tanks of a copper-nickel alloy, soldered on the inside with a lead-tin solder, it was observed that if a developing solution remained in the tank for a short time the developer gave very bad fog. The solder with which the seams of the tank were soldered appeared to be etched slightly, and the original lustre of the metal had disappeared and was replaced by a dark, grainy deposit. The alloy itself was unaffected as far as could be detected from its physical appearance. A series of tests definitely proved that this excessive fog was a result of the tin constituent of the solder passing into solution, due to the flow of an electric current through the solder, the solution, and the alloy. When the joints were soldered on the outside of a folded joint, no developer fog was produced and corrosion was much less.

Corrosion was also observed due to the same cause when a tank made from this alloy and soldered on the inside was used as a container for an acid fixing bath, except that the alloy was corroded instead of the solder. With acid fixing baths the most rapid corrosion of a Monel metal tank usually occurred just above the air-liquid line.

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[2] *The Resistivity of Various Materials Toward Photographic Solutions*, J. I. Crabtree and G. E. Matthews. Brit. J. Phot. Vol. 70 (1923) pp. 366, 385; also Ind. & Eng. Chem. Vol. 15 (1923) p. 666.

An extended study of these aspects of corrosion has been made, and results are given in two papers.[3]

If a large scale installation is contemplated, tests should be made of the metallic material and fabrication methods before the construction[4] of the equipment is undertaken.

METHOD OF TESTING METAL SAMPLES

An accelerated corrosion test on a given sample will invariably give valuable information regarding (a) its relative resistivity, and (b) any detrimental action on the photographic solution.

Absolute data can be obtained only by practical trials but, over a long period of testing, the results of accelerated tests have been invariably confirmed by practical use.

Preparation of the Sample

To make an accelerated test, a representative piece of metal or alloy,[5] for example, a sheet 1 inch wide by 3 to 5 inches in length, preferably cut by shearing, should be cleaned free from oil or grease by immersion in benzene (benzol) for about 1 minute followed by drying with a clean cloth. The specimen strip is then half immersed in a definite volume of the particular photographic solution contained in a clear wide-mouthed bottle (4 to 16 ounces, depending upon the sample length) so that each square inch of total area of the material will have approximately 1 to 3 ounces of solution for contact. The bottle may be (a) tightly stoppered, (b) loosely stoppered, or (c) left open, depending on the information desired. When the bottle is closed, the severity of the test is increased because of the more concentrated vapor phase, and such a test has proved valuable in studying the action of acid fixing baths on various stainless steels and similar materials. However, in studies of the fogging properties of metals and alloys on developers, it was found desirable that the bottles at room temperature be open to access of air to secure the maximum effect with some materials.

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[3] *The Effect of Electrolysis on the Rate of Corrosion of Metals in Photographic Solutions*, J. I. Crabtree, H. A. Hartt, and G. E. Matthews. Ind. & Eng. Chem. Vol. 16 (1924) p. 13, and *Corrosion of Monel Metal in Photographic Solutions*, J. I. Crabtree and G. E. Matthews. Ind. & Eng. Chem. Vol. 16 (1924) p. 671.

[4] Details of testing metal samples, examples of typical corrosion effects and other useful data supplementing the information in this pamphlet are given in the book, *Photographic Chemicals and Solutions*, J. I. Crabtree and G. E. Matthews. American Photographic Publishing Co., Boston, Mass.

[5] Free from impurities such as ordinary iron, copper, etc. (For stainless alloys see manufacturers' instructions for passivating if required.)

Storage and Testing

Duplicate tests should be made at 65° to 70°F (18° to 21°C) and at 110°F (43°C) and should be continued with observations after 18 to 24 hours, 2 days, 4 days, 1 week, 2 weeks, and 1 month or longer. The results at high temperature should not be regarded as conclusive but rather as indicative. In any case, the photographic properties of a given solution should be compared with those of an equal volume of the solution stored in a container of duplicate dimensions under the same conditions but without the material under test. In the case of a developer this can be done by developing two pieces of identically exposed film for the recommended time, one in the test solution, the other in the control solution. The negatives can then be compared for fog, contrast, speed loss, etc. Details of tests of a series of metals and alloys for their fogging action on several developers have been published.[6]

Observations should be made regularly as indicated during the progress of the test noting the appearance of the samples and, if a developer is being tested, its fogging tendency determined at 68°F (20°C) by developing therein for a normal time a film with a representative unexposed area. If necessary, water should be added and mixed with the solution at frequent intervals to replace that lost by evaporation. Care should be taken to remove the test material when adding water or removing the solution for tests or replacing it. When only resistivity is being studied, a fresh lot of the solution being used may periodically replace the original volume. The condition of the metal should be noted for the portion exposed to the vapor as well as that immersed in the solution and also the area in the vicinity of the air line of the solution.

Effect of Nature of Solution on Corrosion

Important factors with developers are the alkalinity (pH) of the solution and the concentration of sulfite. Representative developers according to increasing alkalinity are the Kodak Formulas D-76, DK-60a, D-72 (various dilutions), D-19, and D-8. The developers of intermediate alkalinity (DK-60a and D-72) are well suited to a study of the effect of copper and other metals in giving rise to aerial fog and inducing aerial oxidation of the solutions.

For testing the action of fixing solutions, it is desirable to employ both fresh and partially exhausted samples of the particular type of solution. Representative types are the widely used Kodak Acid Hardening Fixing Bath F-5 and the Kodak Chrome Alum Fixing Bath F-23. The action of other solutions such as toners and bleaching baths on metals may be tested in the usual way, while the effect of the metals on the photographic properties of the solutions may be determined with suitable photographic tests, processing similar pictures or strips in both the solution in question and in a control solution.

Tests with Lacquers and Plastics

Tests similar to those described can be used to test protective lacquer or paint coatings on metallic and nonmetallic materials. The use of closed containers at 110°F (43°C) may be necessary, as for example to show the effect of highly alkaline developers on certain plastics, or in the case of ordinary developers to leach fogging sulfur compounds from rubber and similar products.

In addition to determination of the resistivity of the material and its effect on the photographic solution, observations should also be made of any tendency to chip away or distort with increased temperature.

VALUE OF VARIOUS METALLIC MATERIALS

Only the practical application of the results of tests on the various metals will be considered in this article; the original papers should be consulted for more detailed information.

Metals

Lead and nickel are the only metals tested which appear to be of any special importance for use with photographic solutions, although iron is of value for particular purposes. Lead, nickel, and wrought iron tanks or piping can be used satisfactorily for most developing solutions although lead is attacked by strongly alkaline developers. Iron is attacked more or less by most developers in the presence of air and tends to form oxides and hydroxides in the solution so that it is important to filter out such particles before use. (See section on "Care of Equipment," page 27.) Tanks lined with lead or nickel can be used for fixing solutions, but they are slowly attacked, become coated with silver, and must eventually be replaced. Silver withstands continuous contact with developers and has been used as a clad material on steel. Tantalum,[7] while generally rare and too expensive for anything but small special apparatus, is unique since it did not exhibit any signs of attack in tests with a large variety of photographic solutions, including corrosive bleaching and acid solutions.

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[6] *The Fogging Properties of Developer Solutions Stored in Contact with Metals and Alloys,* J. F. Ross and J. I. Crabtree. Amer. Phot. *23:* (1929) p. 254.

[7] Fansteel Metallurgical Corp., North Chicago, Ill.

Plated Metals

Galvanized iron has long been used for the manufacture of washing tanks although it is not entirely suitable for this type of apparatus. Vessels made of this material must not be used, however, for mixing developers which contain sodium bisulfite, because the bisulfite attacks the zinc coating, forming sodium hydrosulfite which causes fog.[8]

Nickel-plated brass is satisfactory for small developing tanks which are used intermittently. Metals plated with silver, either by deposition from an exhausted fixing bath or by electroplating, are more resistant to developing solutions according to the homogeneity of the silver coating, but their resistance toward fixing baths is only slightly greater than that of the unplated metals. Aluminum and cadmium-coated metals do not satisfactorily resist photographic solutions. Chromium-plated metals would probably be satisfactory if it were possible to secure a continuous nonporous coating over the base metal, but no such coatings are available to date. Lead-coated iron can be used for developing and washing tanks if the iron base-metal is not exposed, but it is not very satisfactory.

Plated metals and alloys are always open to the objection that as soon as some of the plating wears off, exposing the other metal underneath, electrolytic corrosion sets in, and disintegration takes place rapidly. Such effects are apt to occur when the thickness of the protective layer is less than about 0.002 inch.

Alloys

Of the numerous known alloys, Monel, Inconel,[9] and the austenitic stainless steels [10] such as 18-8 (Type 304) and the relatively nonpitting varieties containing molybdenum (Types 316 and 317) are the only ones which have been adopted to any great extent for photographic use.

Inconel, a chromium-iron-nickel alloy, is superior to Monel for use with acid fixing baths in open vessels, either fresh or with the acidity maintained during use, since it is not so susceptible to general or air-line corrosion and because this passive alloy does not plate out silver with exhausted fixing baths and become attacked as does Monel. With acid fixing baths Inconel exhibits properties somewhat like the non-molybdenum 18-8 Stainless Steels, such as Types 302, 304, 321, and 347, since all of these materials are attacked and pitted in the vapor over acid fixing baths, particularly when the vessels have been closed for sufficient time. Variations in room and solution temperatures increase the tendency for corrosion probably because of the condensation on the metal of water vapor containing sulfur dioxide. Practical tests have indicated that molybdenum stainless steels (Types 316 or 317) are more resistant than Inconel for use with acid fixing baths. Inconel, like the stainless steels, exhibits maximum resistance to corrosion when it has a relatively smooth ground and polished finish.

Most samples of 18-8 Stainless Steel with low carbon content (0.08% max.) are resistant to developers and are also sufficiently resistant to acid fixing solutions provided that the vessels are either (1) entirely filled with solution, (2) without a cover and therefore open to the free movement of air, or (3) used intermittently and thoroughly washed and cleaned regularly. Stabilized forms of 18-8 Stainless Steel containing a small percentage of titanium (Type 321) and more recently the superior columbium (Type 347) represent an improvement over the older 18-8 steels, especially for tank construction where welds are required. Another form that has somewhat higher corrosion resistance contains chromium 19-22%, nickel 10-12% (Type 308), and has the advantage that it costs only slightly more than the 18-8 (Type 304) alloy. Marked improvement of the 18-8 and similar steels relative to their corrosion resistance to acid fixing baths and their vapor has been realized by incorporating a small percentage (2-4%) of molybdenum (Type 316 with molybdenum 2-3% and Type 317 with molybdenum 3-4%), the alloy with the higher molybdenum content being the most resistant. The relative cost of such steels, however, is somewhat higher (25 to 50%) than the 18-8 Type 304 Stainless Steel, but the molybdenum addition provides ample resistance of the alloy to the sulfur dioxide present both in and above the solutions and prevents pitting, which frequently causes failure of the 18-8 Stainless Steels. These molybdenum stainless steels, therefore, are preferable for the construction of tanks, supply systems, and equipment for continuous use and where sulfur dioxide laden vapors may be confined indefinitely.

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[8] *The Fogging Properties of Developing Solutions Stored in Contact with Various Metals and Alloys*, J. F. Ross and J. I. Crabtree. Amer. Phot. Vol. 23 (1929) p. 254.

[9] *Inconel as a Material for Photographic Film Processing Apparatus*, F. L. LaQue, J. Soc. Mot. Pict. Eng. *24:* (1935), p. 357.

[10] The various kinds of stainless steels in wrought form are properly specified according to composition range by the use of the type numbers assigned by the American Iron and Steel Institute. To illustrate, an 18-8 Stainless Steel with chromium 18-20%, nickel 8-10%, and carbon 0.08% max. and manganese 2.0% max. is given as Type 304; an 18-8 Mo (molybdenum) modification containing chromium 16-18%, nickel 10-14%, carbon 0.10 max. and molybdenum 2-3% is given as Type 316. For a table of representative types and composition see *Newer Types of Stainless Steel and Their Application to Photographic Processing Equipment*, H. A. Smith, J. Soc. Mot. Pict. Eng. *30:* (1938), p. 410. Stainless Steels in cast form, however, are specified by the designations of the Alloy Casting Institute (see footnote reference, page 3).

The selection of a stainless steel for a construction material in connection with photographic equipment depends, therefore, upon the type of use the equipment will receive and the fabrication requirements necessary when forming the equipment.

The welding of stainless steels must be done correctly or corrosion may occur at the welded joints (see discussion on page 30). Wrought austenitic stainless steels with low carbon (carbon 0.08 max.) are not required to be heat treated and quenched unless the part has been subjected to considerable stresses such as occur in certain deep drawing and forming operations.

In addition to the above materials which can be obtained in sheets as well as other forms, there are two types of material of a highly corrosion-resistant character which are not available in all forms. The first is the high silicon iron type known commercially as Duriron.[11] Although available only in castings, this alloy has frequently been specified for sewers where resistance to chemical attack is required. Durichlor,[11] an interesting development of this type, also contains about 3% molybdenum and has increased resistance to strong acids, such as hydrochloric, and to acid oxidizing halogen bleaching solutions, but it is not suitable for use where acid sulfites or appreciable moist sulfur dioxide are present as with acid fixing baths.

The second type of highly corrosion-resistant alloys, which appear to be of value when special photographic solutions are considered, consists of complex compositions containing nickel, molybdenum, iron, chromium, and other elements. Of this type are some of the Hastelloy[12] materials, Illium G and R,[13] Durimet T,[11] and Durimet 20,[11] as well as other special cast alloys (see footnote reference, page 3).

COATED METALS

Enameled Steel

Enameled steel is used extensively for small trays and tanks, and has proved fairly satisfactory. When the undercoating of steel is laid bare by the chipping away of the relatively brittle vitreous enamel, it corrodes very rapidly, and the vessel is rendered useless. Smooth, hard enamel coatings are resistant to weak acids used in photographic practice, but with developers and alkaline solutions the surface becomes etched, making it difficult to clean. Dye solutions permanently discolor such roughened surfaces of enamel.

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[11] Duriron Co., Inc., Dayton, Ohio.
[12] Haynes Stellite Co., Kokomo, Ind.
[13] Burgess-Parr Co., Freeport, Ill.

Glass Enameled Steel

Equipment having very satisfactory resistance to most photographic solutions (except strongly alkaline developers) is available in the form of mixing tanks and agitators (5 gallons upwards) suitable for motion picture laboratory use. Such equipment is made by fusing resistive silicate enamels onto substantial steel shells at a temperature of about 980°C (1800°F). Advantages claimed are less weight and bulk and greater heat conductivity than with cast metals or earthenware. The glass enamel on the steel is much more resistant to breakage than ordinary enamel since it is actually fused onto the metal. Repairs in the event of breakage, however, are difficult to make without returning the entire unit to the factory.

Lacquered and Painted Metals

A satisfactory photographic lacquer consists of asphalt paint or a mixture of asphalt paint with rubber cement, the latter serving to overcome the slight brittleness of the asphalt coating. Baked japan is very satisfactory, but none of these materials resist developing solutions containing a high percentage of alkali. Freshly applied asphalt paint often produces a scum on the developer.

Kodacoat[14] Paint represents a satisfactory material for protecting a metallic surface from corrosion when subjected intermittently to photographic solutions or their vapors. Several coats should be applied to secure maximum protection. A thicker protective coating may be obtained by using a hard asphalt. This material requires melting and must be applied hot for best results. Hard asphalts usually melt between 250°F to 300°F.

Halogenated rubber paints prepared from Parlan[15] and some other rubber paints, such as Pliolite,[16] are also fairly resistant to the action of developers and fixing baths. Some types of Bakelite lacquers, such as Larcoloid,[17] are quite resistant to the action of corrosive vapors.

Racks, stirrers, and tanks which are used intermittently can be protected effectively from corrosion in acids and alkalis by dipping or spraying or painting with several coats of Korolac[18] (No. 495) after treatment with a primer (Korolac No. 691). With large surfaces, a better bond is secured by covering the area with a coarse metal screen before treatment with the lacquer.

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[14] Eastman Kodak Co., Rochester, N. Y.
[15] Hercules Powder Co., Wilmington, Del.
[16] Pratt & Lambert Co., Buffalo, N. Y.
[17] Larkin Co., Buffalo, N. Y.
[18] B. F. Goodrich Co., Akron, Ohio.

Coatings of special phenol-formaldehyde resins on metal surfaces, which have been suitably baked after application to give good abrasion and corrosion resistance, are available under trade names such as Heresite[19] and Lastiglas.[20] Materials for these coatings are available but are preferably applied by the manufacturer. The treated surfaces show promising resistance to many photographic solutions.

As a general rule, it is best to use paints and lacquers on surfaces that receive only intermittent exposure to solutions or their vapors rather than immersion in the solution, because it is very difficult to treat a surface with a paint or lacquer so as to render it completely impervious to the penetration of a liquid.

It is important to protect the exterior as well as the interior surfaces of tanks to prevent corrosion of the base metal. Consideration should be given to the possibility of abrasion and pressure to which the exterior surface may be subjected. A large heavy tank resting on a beam, for example, would soon press through any protective coating and allow corrosion of the base metal to occur. All surfaces which are likely to be abraded or worn away should be recoated frequently.

Laminated Metals

Several types of laminated or clad metals are available which consist of a thin sheet of corrosion-resistant metal on one or both sides of a thicker metal base such as steel. For example, lead, nickel, Inconel, silver, and various stainless steels have been integrally welded onto steel or iron in manufacture. Such materials are sometimes less expensive and more readily obtainable than the solid alloys, and it is possible that they will find some uses in photographic processing work. Certain precautions in selection and fabrication, however, should be emphasized. Careful selection of these materials must be made with reference to the suitability of the cladding metal for the intended use and the thickness of cladding. Special joining and welding precautions[21] are also necessary to avoid exposure of the base metal and to prevent inhomogeneities and dilution with the iron base metal at the joints, each of which may lead to attack. The steel exterior of laminated metal vessels should be protected from corrosive attack by the use of suitable protective coatings such as those described above unless the steel is clad on both sides. (See also section on deep tanks, page 22.)

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[19] Heresite and Chemical Co., Manitowoc, Wis.

[20] Bishopric Co., Cincinnati, Ohio.

[21] *Nickel and Nickel Alloys*, The International Nickel Co., New York, N. Y. (1941), pp. D29-30, G4, and M101-115.

NONMETALLIC MATERIALS

Several satisfactory materials for use in handling photographic solutions on a large scale are to be found in the nonmetallic group. Since it is not practical to deal specifically with all of these materials because of the continual introduction of new ones, the testing methods described on page 5 can be employed to determine their suitability.

Cement and Concrete

Tanks made of reinforced concrete faced with cement have been used to some extent by photofinishers for wash tanks and in a few cases for developer tanks. They are generally unsatisfactory for use for fixing baths because of the tendency for disintegration when the hypo crystallizes in the pores of the cement. Steel reinforcement is necessary for all sizes of concrete tanks. The surface preferably should be treated with several coats of an asphaltic paint, such as Kodacoat, or with a hard asphalt. (See method of application of asphalt on page 18.)

When large tanks are installed, the floor load should be checked carefully and the tank should be set on concrete beams to raise it off the floor and permit easy cleaning around and under the tank. The upper edges of a concrete tank should be protected with a cypress wood facing to prevent chipping.

Glass

Glass apparatus, which is well annealed, free from ribs, and with the corners of small trays and tanks rounded off, is quite satisfactory and is one of the most resistant materials available. For the storage of strong alkalis, special resistant glass should be used. Owing to its fragility, however, common glass is not suitable for large trays and tanks. Pyrex glass piping and centrifugal pumps have become available and can be used with proper care.

An opal plate glass, known as Vitrolite, represents a satisfactory surface for bench or table tops where chemicals are to be used. It is fairly resistant to most photographic solutions except strong alkalis, and it can be kept clean easily. Like other glasses, this material is brittle, and therefore, care must be used that it is not struck with a metal object.

A disadvantage common with stoneware or Alberene is the ever-present possibility of breakage of glassware if dropped on such surfaces. This can be avoided by using a sheet of rubber matting on the surface where glassware is to be placed.

Impregnated Fibrous Materials

Trays or tanks prepared from paper or other fibrous materials impregnated with varnish or lacquer develop cracks with use; thus the solutions have access to the under layers. Such trays and tanks are entirely unsatisfactory for use with solutions containing strong alkalis, or with fixing baths, because these solutions disintegrate the fibrous materials through crystallization, as explained later under "Porcelain and Glazed Earthenware," page 15. Small fiber trays carefully impregnated with a high melting wax are satisfactory for intermittent use if carefully handled.

Containers made from most laminated phenolic condensation products can be used with photographic solutions, with the exception of strong oxidizing solutions. These materials are not usually resistant to strongly alkaline solutions. Representative material is available in sheet, rod, and bar stock and as pipe, and has been used with success for processing machine parts.

Wood

Wood is fairly satisfactory for developing, fixing, and washing purposes, and is cheaper than any other available material. Wooden equipment can be quickly fabricated and requires only the common tools usually at hand. It has the disadvantage that, unless strongly braced, the tanks have a tendency to warp out of shape. This tendency is minimized with round tanks, which should be well braced with iron rings that are tightened as much as possible after the tank has been soaked thoroughly by filling it with water and allowing it to stand for several days.

If wooden tanks are used as containers for fixing baths, they should preferably be constructed of paraffined wood as described below. Hypo, if allowed to crystallize on the sides, penetrates the wood in time and causes it to splinter or crack. This can be avoided by keeping the tank filled as much as possible.

In many localities fungus growths accumulate on the outside of the washing tanks and must be removed frequently, while the inside of the washing tanks often becomes coated with a layer of slime which necessitates frequent cleaning. Slime formation is not peculiar to wooden tanks, but the action of the fungus or bacteria may be more destructive to wood. Wooden containers also become permanently discolored if they are used for dye solutions. The most satisfactory varieties of wood for the construction of tanks are cypress, spruce, redwood, maple, and teak.

Paraffined Wood

Although certain woods such as cypress and teak are frequently used for the construction of containers for photographic solutions, paraffin impregnated wood is much more satisfactory. It possesses the advantage that it does not tend to accumulate slimy layers as rapidly as unwaxed wood. The chief disadvantage of paraffined wood is that it is too heavy for the construction of large equipment which is to be handled manually. It is also quite brittle and breaks easily if dropped. Methods of impregnating wood with paraffin have been investigated by Eberlin and Burgess,[22] who found that the best results were obtained with cypress and spruce by soaking them in water for 12 hours and then immersing them in molten paraffin wax for 2 hours at around 250°F (120°C).

The soaking serves to swell the wood, and in the hot paraffin bath the water in the pores is replaced by paraffin. The wood should be wiped thoroughly with a cloth when taken from the paraffin bath so that the excess wax is removed. Watertight joints with paraffined wood are best made by grooving the pieces of wood to be joined together, as for a T-joint, and tightly inserting a small piece of unparaffined wood in the groove. When placed in water, the untreated strip swells and completely caulks the seam.

Plastic Bonded Plywood

Among wood products, resin or plastic bonded plywood has been used with considerable success for constructing intermediate and small-scale tanks, trays, and troughs for use with photographic developers, fixing baths, and other solutions. Such tanks should be joined carefully and the surface, both inside and out, lacquer treated with a suitable protective paint or lacquer (see page 11) to decrease water absorption.

Porcelain and Glazed Earthenware

Porcelain, glazed biscuit ware, and tile material are usually unsatisfactory because the glaze invariably cracks, causing minute fissures into which the solution penetrates and crystallizes. The crystals then grow and cause the biscuit ware to disintegrate, incidentally causing the glaze to chip. Tanks of high-grade, dark brown earthenware,[23] glazed on both sides, are especially recommended for storing ordinary developing and hypo solutions, but they should not be used with strong alkalis.

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[22] *Impregnating Wood with Paraffin*, L. W. Eberlin and A. M. Burgess, Ind. Eng. Chem. Vol. 19 (1927) p. 87, Revised 1928.

[23] The term "Chemical Stoneware" is a general term used by the manufacturers to describe such materials.

A form of hard glazed chemical stoneware was introduced which was claimed to be free of all internal fissures, lighter, and thinner than the older types but equally strong and chemically resistant.[24]

Rubber, Rubber Composition, Carbon and Graphite Compositions, and Asphaltum Materials

Pure hard rubber withstands practically all photographic solutions at normal temperatures. Hard rubber thermoplastics (said to be sulfur free) were introduced in 1933.[25] These appear promising for the construction of small trays and tanks for photographic work.

For certain types of installations, hard rubber piping is very satisfactory because it is light and can be threaded easily. Its chief disadvantage is its brittleness. Iron pipe lined with hard rubber, which is firmly cemented in the pipe, represents a very satisfactory type of piping for photographic solutions. It possesses the advantages over ordinary hard rubber pipe that it does not require support every few feet and is not subject to breakage by impact.

Some so-called hard rubber tanks are made from a mixture of asphalt, or rubber composition with an excess of mineral filler. Such tanks are somewhat brittle, warp under heat, and when used as containers for salt solutions disintegrate in the same manner as porous earthenware. Smooth surfaces minimize the tendency to etching by reducing the surface area; thus, disintegration due to the growth of crystals in porous surfaces is less likely to occur.

Black hard rubber sheet or fabric-backed rubber sheet can be used for bench tops or sink ledges where photographic chemicals are to be handled. The sheets should be cemented to a wood table top with waterproof cement such as Plastikon Cement, supplied by the B. F. Goodrich Co., Akron, Ohio.

Rubber cements have been developed which produce a highly tenacious bond between hard rubber and metal, wood, porcelain, and other surfaces, and which have fairly high resistance to corrosive attack of acids and alkalis.

According to Fritz and Hoover,[26] vulcanized rubber can be compounded to resist actual immersion for long periods in organic acids and solutions of salts and alkalis. Above 150°F (65°C) the effects of oxidation, diffusion, and absorption become aggravated. A three-ply construction of soft and hard rubber is described by these authors which it is claimed represents an improved type of material for coating the surface of metal tanks.[27]

Tanks can be constructed economically from steel sheets on which a thin (1/8 inch) soft black rubber sheet is cemented intimately. The rubber is permitted to extend over the edges of the steel, and "squeezed joints" are made to form the bottom and walls of the tank by bolting two opposite sides together and allowing the rubber sheets to protrude at the join. When the bolts are drawn up, the two rubber sheets are pressed together and form solution-tight joints.

Some synthetic rubber-like elastic materials, for example Koroseal,[28] a polymer of one of the vinyl halides, and the chloroprene base Neoprenes,[29] appear superior to the products made from natural rubber in resistance to deterioration by oxidation (aging), oxidizing solutions, strongly corrosive acid and alkaline solutions, and sulfur dioxide. In sheet form these materials can be used for lining trays, troughs, and tanks, and for gaskets.

Rubber sheeting and rubberized cloth are often used for coating the inside of wooden trays and troughs. They are very satisfactory provided that the surface is not subjected to much abrasion during use.

Cotton fabric coated with Koroseal, a rubber-like material, is resistant to most photographic solutions. It possesses advantages over ordinary rubberized cloth in maintaining its properties better with age and in the presence of sulfur dioxide.

Tank linings and even small tanks themselves can be made by constructing a form of wire mesh material and coating it several times, preferably by dipping it in a viscous Koroseal solution to close the openings and build up sufficient thickness to withstand solution pressure. It is important to use a sufficiently viscous solution, because the Koroseal solutions do not readily bond to the metal but only closely surround the supporting metal.

Cheap rubber sheeting or tubing often contains an excess of free sulfur which reacts with photographic developers and causes chemical fog.[30] For this reason it is doubtful whether certain artificial rubber materials made by the use of polysulfides can be employed in such solutions. Pure gum rubber materials, while quite satisfactory, are surpassed by synthetic materials such as Koroseal and Neoprene. Since solutions used in a tray or trough are usually in contact with the rubber for only a relatively short time, more corrosive solutions can be used than in the case of a rubber-lined tank. For handling long lengths of wide film (Cirkut film), a rubberized tray is excellent.

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[24] Chem. & Met. Eng. *40:* (May 1933) p. 270; also Ind. & Eng. Chem. Vol. 25 (Sept. 1933), Adv. Sec. p. 35.

[25] Ind. & Eng. Chem. Vol. 26 (Feb. 1934) pp. 123-129.

[26] *The Chemical Resistance of Rubber as an Engineering Material*, H. E. Fritz and J. R. Hoover. Reprint of Symposium on Rubber, Amer. Soc. Testing Materials, March 9, 1932, p. 79.

[27] Joint and corner construction of rubber lined tanks and other useful data are described and illustrated in the book, *Photographic Chemicals and Solutions*, American Photographic Publishing Co., Boston, Mass.

[28] B. F. Goodrich Co., Akron, Ohio.

[29] *The Neoprenes*, D. F. Fraser and N. L. Catton, Report No. 42-43, Sept. 1942. E. I. duPont de Nemours & Co., Inc., Rubber Chemicals Division, Wilmington, Del.

A flocculent precipitate is produced when some grades of soft rubber are placed in a developer solution for several days. This precipitate tends to settle on film and produce scum markings. The use of rubber sheeting giving such precipitates should be avoided.

Rubber buckets, such as those made of Flexite,[31] represent useful containers for the intermittent handling of solutions and are resistant to the corrosive attack of most photographic solutions. The handle should preferably be made of stainless steel.

Carbon and graphite compositions of highly corrosion-resistant character are available in pipe, pipe fittings, valves, and other forms. These have many possible applications although experience with photographic baths as yet is not very extensive. These materials are brittle like hard rubber and many nonreinforced resins. However, some types can be threaded with standard pipe tools. Rope wrenches should be used in assembling, and care in sawing or shaping must be exercised to avoid thin sections and to locate or shield the part suitably from mechanical abuse.[32]

Kodacoat Paint, as mentioned on page 11, represents a satisfactory material for coating wood, stone, and metal to protect them against the intermittent attack of acid or alkaline solutions. It can be applied with a brush, and several coats should be used to give maximum protection.

A good grade of hard oxygenated asphalt, such as Kodak Oxygenated Asphalt,[33] has been found to be a satisfactory protective coating for use with all kinds of photographic solutions. This material is applied, while hot, as a thick coating over the metal or wood, and if a smooth surface is desired, the coating can be smoothed out by the use of a blow torch. This coating is normally somewhat tacky and in hot weather adheres to metal articles. Therefore, if a photofinishing tank is coated with this material, the upper edges of the tank should be provided with wooden supports for the metal rods carrying the hangers.

Thermoplastic Artificial Resins, Cellulose Ester and Ether Materials

The number of thermoplastic artificial materials has been notably extended in recent years and a wide range of types is available[34] in sheet, rod, tubing, pipe, and other forms. These materials combine advantages in resistivity to attack and ease in fabrication for small apparatus and parts.

Plastics of acrylate type[35] and Tenite II[36] (cellulose acetate butyrate) are resistant to almost every type of photographic solution and have the advantage that they can be cut easily and joined by the use of the proper adhesives and cements recommended for each material. Such products are useful for the construction of small apparatus including trays, tanks, film hangers, and intricate processing devices. Tenite II is joined by the use of methods similar to those described for the earlier cellulose ester materials.[37]

Produced in the form of piping of standard and threaded sizes are materials such as Tenite II,[38] Saran,[39] a vinylidine chloride derivative, and Tygon,[40] a vinyl chloride product.

Practical experience with these materials in contact with photographic processing solutions is lacking, but tests indicate the materials to be promising. Since the pipes are thermoplastic, they are subject to distortion unless properly supported. They should also be kept away from highly heated locations. Saran softens over the range of 150° to 250°F, while the softening range of Tygon is somewhat lower.

Nitrocellulose lacquers are useful for coating wooden articles such as racks for handling motion-picture film, although several coatings are usually necessary. Small apparatus constructed of nitrocellulose sheeting is satisfactory for use with almost every type of aqueous solution.[41] Wooden tanks lined with this material have also proved satisfactory. A disadvantage of such sheeting is that it is very inflammable.

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[30] *Chemical Fog*, J. I. Crabtree. Amer. Ann. Phot. Vol. 33 (1919) p. 20.

[31] B. F. Goodrich Co., Akron, Ohio.

[32] *Carbon, Graphite and Karbate as Materials of Construction*, L. C. Werking, Trans. Inst. Chem. Eng. *35:* No. 4, pp. 489-503; see also *Impervious Carbon Equipment*, L. C. Werking, Chem. & Met. Eng. *46:* No. 6 (June 1939), pp. 362-364.

[33] Eastman Kodak Company, Rochester, N. Y.

[34] *Plastics Catalogue* (an Encyclopedia of the Plastics Industries) (1943), Plastics Catalogue Corporation, 122 East 42nd St., New York, N. Y. Exhaustive information on plastic materials including synthetic rubber materials, manufacturers, molders, equipment, etc.

[35] For example, see booklet *Lucite Manual*, E. I. duPont de Nemours & Co., Plastics Dept., Arlington, N. J.; also *Plexiglas Fabricating Manual*, Rohm and Haas Co., Philadelphia, Pa.

[36] Tennessee Eastman Co., Kingsport, Tenn.

[37] *Plastic Cellulose in Scientific Research*, K. Hickman and D. E. Hyndman, J. Frank. Inst. Vol. 207 (1929), p. 231.

[38] Transparent Tenite II Pipe, see announcement Chem. Eng. News *20:* No. 21 (Nov. 10, 1942), p. 1489.

[39] Dow Chemical Co., Midland, Mich.

[40] U. S. Stoneware Co., Akron, Ohio.

Slate and Alberene Stone

These materials are suitable for constructing large rectangular tanks for containing developing solutions. For fixing solutions, Alberene stone (a gray, finely crystalline variety of soapstone) is quite satisfactory, but slate is not recommended as it often splits along planes of cleavage as a result of crystallization. Some varieties of soapstone are not resistant to fixing baths and tend to disintegrate where the sodium thiosulfate crystallizes out. Developers also attack these varieties of soapstone chiefly above the air line of the solution and produce disintegration.

A satisfactory cement for joining large pieces of soapstone, as in constructing a tank, can be prepared from one part whiting, two parts litharge, thoroughly mixed and made into a putty with boiled linseed oil. A mixture of litharge and glycerine is recommended for cementing small fittings into the tanks. Glucarine B[42] is a satisfactory substitute for glycerine.

A hard oxygenated asphalt can sometimes be used effectively to repair cracks in a soapstone sink. It has the advantage of being plastic so that it yields with expansion and contraction of the stone.

PRACTICAL SUGGESTIONS

The choice of material for construction depends both on its physical properties and chemical resistivity. Resilience and freedom from brittleness are obviously required in film clips, hangers, etc.; ability to hold shape and resist pressure are quite important in deep tanks. Materials suitable for constructing various types of photographic apparatus are as follows:

Small Apparatus (Clips, film hangers, etc.)

Low carbon 18-8 Stainless Steel such as Type 304 (carbon 0.08% max.) is satisfactory for intermittent use in ordinary processing solutions. However, Stainless Steels, Types 316 and 317, containing molybdenum 2-3% and 3-4%, respectively, are more corrosion resistant for general use. These are recommended as representative of the most satisfactory materials known and have been used successfully in most photographic solutions except intensifiers containing mercuric salts provided that the use was followed by thorough washing. Inconel has properties somewhat similar to those of Type 304 Stainless Steel, and the surface remains bright in the presence of the silver in used fixing baths. Nickel and Monel, however, while sufficiently resistant to ordinary developing and fixing solutions tend to darken and to plate out silver from used fixing baths. This deposit can also occlude undesirable complex silver thiosulfate compounds.

As has been indicated above, special film and plate hangers can be constructed of plastics of the acrylate type, canvas reinforced resins such as Syntham and Formica, Tenite II, or even nitrocellulose. Although breakable, such hangers represent useful substitutes for those of metal. The nitrocellulose material, however, possibly is not so desirable because it is highly inflammable.

Trays, Dishes, and Small Tanks

Since these containers are generally used for a variety of purposes, they should be resistant to most photographic solutions. Suitable materials are glass, enameled steel, hard rubber, teakwood or spruce impregnated with paraffin wax, wood or metal coated with sheet rubber or rubberized cloth, wood coated with a hard oxygenated asphalt, and well-glazed porcelain or stoneware. Plioform,[43] a rubber product that does not contain sulfur, represents a promising material for the manufacture of small trays and tanks. It is much more resilient than most types of hard rubber. Small amateur trays made of heavy cardboard impregnated with a high melting wax are fairly satisfactory provided that they do not receive rough treatment (see wire mesh coated tanks, page 17).

Small open tanks of austenitic stainless steel, for example 18-8 Types 304, 321, or 347, Inconel, or Monel are satisfactory for intermittent developing, fixing, and washing use or for continuous developing and washing service. Suitable and regular cleaning of the surface of the stainless steels and Inconel is essential to insure maximum resistance to attack and long life. Small tanks of Stainless Steel, Types 316 or 317, can be covered and used indefinitely as containers for acid fixing baths with only occasional cleaning.

Tenite II, Bakelite, and various other artificial resins such as the acrylates are very satisfactory. In large quantities these can be molded; in small quantities, construction methods indicated above can be used.

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[41] *Plastic Cellulose in Scientific Research*, K. Hickman and D. E. Hyndman, J. Frank. Inst. Vol. 207 (1929), p. 231.

[42] Glyco Products Co., Inc., 230 King St., Brooklyn, N. Y.

[43] Goodyear Tire and Rubber Co., Akron, Ohio.

Deep Tanks (for motion-picture work and commercial photofinishing)

Alberene stone, well-glazed chemical stoneware, and wood (cypress) are suitable for developing and fixing baths. Lead-lined wooden tanks are fairly satisfactory for developing solutions provided that the joints are lead burned and not soldered. Glass enameled steel tanks also are satisfactory for use with most photographic solutions.

Iron tanks lined with hard rubber sheeting or, preferably, with soft rubber sheeting (sulfur-free) represent a useful type of container that is resistant to corrosive attack. Overlapping expansion joints can be used with hard rubber, and "squeezed joints" with soft rubber. The latter are produced by squeezing together the rubber that protrudes over the edge of the steel at the corner of the tank by bolting opposite sides together.

Plain wooden tanks are usually satisfactory, but they tend to accumulate slime. Storage and circulating tanks made of cypress wood are used extensively in motion-picture laboratories in Hollywood and New York. Tanks of paraffined wood can be used if the wood is properly joined together with strips of untreated wood as explained on page 15. Tanks of Portland cement over concrete have been found satisfactory for developers of low alkali content. For best results, cement tanks should be painted with several coats of an asphalt paint, such as Kodacoat Paint, or else treated with hard oxgenated asphalt. Metal or wooden tanks coated with hard oxygenated asphalt are excellent if the base material is not exposed, due to chipping of the asphalt.

Tanks made of Stainless Steel, Types 316 or 317, with welded seams (see page 30) have been found satisfactory for use with developers, rinse baths, and fixing baths. If the tanks are covered so that the acid vapors of a fixing bath condense on the metal sides, only very slight surface etching may occur. Stainless alloys of somewhat less resistance to the action of acid fixing baths (see Table, page 26) can be employed provided that the tanks are not covered or subject to wide variations in temperature so that sulfurous acid can condense on the surface. The tanks should be cleaned occasionally to insure maximum life, and should be examined for any effects of corrosion.

Metal tanks including those of stainless clad steel, rubber-lined steel, and the solid stainless alloys are most desirably installed so that the tank bottom or sides do not rest against a surface where chemicals and impurities can collect. Unless such surfaces can be flushed off frequently, it is better to avoid them entirely by supporting the tank from ears welded to the sides and to maintain clearance all around.

Covers for Tanks

Covers for tanks serve several useful purposes, namely: (1) They prevent too rapid oxidation of the solution by the air. (2) Dirt, grease, and other foreign matter are prevented from dropping into the solution. (3) The rate of evaporation is reduced. Covers can be made of two types, either to fit over the top of the tank or to float on the solution. In the latter case, the solution is given the maximum protection against oxidation. It is usually unnecessary to use floating covers for very small tanks. For small tanks, satisfactory covers can be constructed of hard rubber, cypress wood, resin bonded plywood, or sheet celluloid. A piece of cellulose ester sheeting (cellulose nitrate, Kodaloid, or acetate butyrate, Tenite), in the form of a shallow tray or boat, is sometimes floated on the solution. Cellulose acetate tends to swell excessively in alkaline solutions such as developers. Resin or plastic bonded plywood protected with resistant paint can also be used for this purpose.

For tanks of 100 gallons or larger capacity, covers can be built of pine wood about 6 inches wide by ⅞ inch thick and grooved with T-joints. One layer should be fitted together tightly and another cut to fit on the first layer at right angles. The boards should be screwed firmly together from one side with Monel or Type 316 Stainless Steel screws, counter-sunk below the surface. The cover should then be given several coats of a nitrocellulose lacquer, and each application allowed to dry thoroughly before the next is applied. If desired, the cover can be made in two separable parts which are fitted together by a shoulder joint. Most covers built of wood become badly warped after a few months of use, but the degree of warping of the one described is reduced to a minimum. For circulating systems, floating covers can be made of molded cellulose ester sheet or Type 316 Stainless Steel with the edges turned up slightly and the seams welded to form a shallow tray or boat. A satisfactory cover for tanks of 50 to 100 gallons capacity can be made of a sheet of Type 316 or 317 Stainless Steel.

Floating covers made of sheet iron and coated with a hard oxygenated asphalt have been used for developer supply tanks for large automatic machines. They are fairly satisfactory for such purposes but should not be used with fixing baths or other solutions.

Tubes, Sprockets, and Idlers for Motion Picture Developing Machines

Hard rubber, lead, Type 304 and Type 316 Stainless Steel, and Pyrex glass have been found satisfactory for developing tubes. Lead gathers a deposit of silver from the fixing bath, and in time this tends to obstruct the tube, but the deposit can be removed by scraping. Brass or copper tubing should not be used since both materials affect developers and are corroded by fixing baths. Metal tubing should not be soldered with solders containing tin. Seamless tubing is preferable.

Developing machine rollers can be molded from Bakelite. The sprockets may consist of a body of Bakelite made by molding or by turning the fabric-reinforced type, and by adding a stainless steel ring to bear the teeth.

Bearings

A satisfactory bearing combination consists of stainless steel in contact with hard rubber or canvas reinforced Bakelite. If the bearing can be maintained fully immersed, lubrication is furnished by the water or the processing baths. If the bearing is not immersed but must be resistant to chemicals spattered on it, graphite impregnated reinforced Bakelite is available which can be used dry, at least at moderate speeds and loads.

Troughs for Reel Processing

Glazed chemical stoneware and wooden troughs lined with sheet rubber or rubberized cloth are satisfactory for practically all ordinary processing solutions. Wood troughs can also be coated with a hard oxygenated asphalt smoothed with a hot iron or torch. Resin bonded plywood represents a light or nonwarping material which, after construction, can be painted with a resisting lacquer or paint. Lead, nickel, 18-8 Stainless Steel, Monel, and Inconel metals are satisfactory for use with developing solutions, and although they are slowly attacked they can also be used with fixing solutions. For acid oxidizing solutions or strong alkalis, hard glazed stoneware troughs are recommended, but the troughs should be emptied after use.

Troughs of almost any metal can be used in an emergency if the interior of the trough is lined with pure gum rubber sheeting or paraffined cloth. This latter lining is applied by coating the interior of the trough with heavy canvas cloth and sticking it to the metal with Cumar Resin (medium hard grade). The cloth is then brushed over with molten hard paraffin wax and the surface finally smoothed off with a hot iron. The cloth should be renewed at frequent intervals. Metal troughs can also be coated with a hard oxygenated asphalt, but great care should be taken to insure that the metal is covered completely and that the coating is free from bubbles. Japanned metalware is satisfactory only for intermittent use.

Piping, Pumps, Faucets, etc.

For transporting developing solutions, hard rubber, iron, Duriron, Inconel, and Types 316 and 317 Stainless Steel piping and pumps are satisfactory and should be used in connection with faucets of similar materials. Hard rubber or iron faucets should be used, especially if continual exposure to the solutions is necessary. For transporting fixing solutions, hard rubber piping, valves, and pumps are recommended. Canvas reinforced Bakelite piping and pumps are suitable for acid fixing baths and for all but the most alkaline developers.

In assembling lines of Type 316 Stainless Steel even well-ground unions were found to leak unless a thin gasket of synthetic Koroseal (page 17) was inserted. Difficulties with the seating of stainless steel valves were likewise avoided by the use of a seat utilizing a Neoprene base material (page 17).

As alternatives to hard rubber may be cited (1) Pyrex glass[44] now available as piping and in centrifugal pumps, and (2) carbon, graphite, and Karbate piping and fittings (page 18). It is also possible that the newer developments in thermoplastic synthetic materials, for example Tenite II and others (page 19), may find application for conducting photographic processing solutions.

Gear pumps of hard rubber represent a simple and economical installation when a flow not greater than 5 to 6 gallons per minute is required. All gear pumps require priming and must be kept wet while running. For a more rapid flow, a centrifugal pump should be installed. Tinned or tin-lined, copper, or brass faucets and piping should be avoided for use with developers and fixing solutions. For conveying distilled water, however, pipe lines and fittings of block tin soldered with pure tin solder are satisfactory. Pure aluminum piping, with valves and faucets of the same metal, is also satisfactory for distilled water lines. It has the advantage over tin and rubber that long spans do not need supporting. Inconel stills, piping, valves, and faucets are also satisfactory for a distilled water system.

Lead piping joints should be "wiped" or lead burned, and not soldered. If silver-plated apparatus is used, the plating should be free from pinholes or scratches.

A suitable packing for pumps consists of asbestos rope twisted with the aid of a little hard grease. Hard rubber faucets, piping, etc., must be protected from impacts or excessive pressure.

The table on page 26 summarizes the above recommendations.

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[44] Corning Glass Works, Corning, N. Y.

CONSTRUCTION MATERIALS FOR PROCESSING APPARATUS*

SOLUTION	STORAGE TANKS	PIPE LINES	RACKS AND HANGERS SPROCKETS AND IDLERS	PUMPS VALVES AND FAUCETS	COILS
Developer	Wood (Cypress) Stainless Steel 316-317 Inconel Stainless Steel 304 Iron† (ungalvanized) Asphalt-coated wood Lead-lined wood Hard glazed stoneware Glass enameled steel Rubber-lined steel	Iron† (ungalvanized) Hard rubber Hard rubber-coated steel Stainless Steel 316-317 Inconel Stainless Steel 304 Nickel Glass	Stainless Steel 316-317 Inconel Stainless Steel 304 Hard rubber Bakelite impregnated fabric Nickel	Stainless Steel 316-317 Inconel Stainless Steel 304 Hard rubber Iron† Monel Nickel Glass (pumps)	Stainless Steel 316-317 Stainless Steel 304 Inconel Nickel Monel Lead
Acid fixing bath not containing silver	Lead Inconel‡ Stainless Steel 304‡ Otherwise same as for Acid fixing bath containing silver	Lead Inconel‡ Stainless Steel 304‡ Otherwise same as for Acid fixing bath containing silver	Inconel‡ Stainless Steel 304‡ Otherwise same as for Acid fixing bath containing silver	Inconel‡ Monel‡ Otherwise same as for Acid fixing bath containing silver	Stainless Steel 316-317 Inconel Monel Lead
Acid fixing bath containing silver	Wood (Cypress) Asphalt-coated wood Hard glazed stoneware Rubber-coated steel Glass enameled steel Stainless Steel 316-317	Hard rubber Soft rubber Rubber-coated steel Stainless Steel 316-317 Glass	Stainless Steel 316-317 Inconel‡ Stainless Steel 304‡ Hard rubber Bakelite impregnated fabric	Hard rubber Stainless Steel 316-317 Inconel‡ Glass (pumps)	Stainless Steel 316-317 Inconel‡
Water	Same as for Developer	Galvanized iron Otherwise same as for Developer	Stainless Steel 316-317 Hard rubber Inconel Bakelite impregnated fabric	Brass Hard rubber Stainless Steel 316-317 Inconel Monel	Stainless Steel 316-317 Inconel Monel Nickel
Distilled water	Block tin Aluminum (pure) Inconel	Block tin Aluminum (pure) Inconel Glass		Block tin Tin lined Inconel Aluminum (pure)	Block tin Tin lined or plated Aluminum (pure) Inconel

*Data for this table were compiled from actual experience of the authors and from information supplied by R. M. Corbin, C. E. Ives, R. S. Scott, J. Folwell, and others to whom the authors are indebted.

†With reservations. See pages 8 and 28.

‡NOTE: These materials become pitted under certain conditions of use especially with acid fixing baths when the vapors of sulfur dioxide are confined within the apparatus. Of the commercially available alloys, Stainless Steel Type 317 is considered to be the most resistant with Type 316 closely analogous. Inconel and 18-8 Stainless Steel with carbon 0.08 max. (Type 304) as clad materials when properly welded are recommended with the same reservations as for the corresponding solid alloys.

Care of Metal Equipment

The life of tanks, trays, and other equipment made of the passive stainless alloys such as the 18-8 Stainless Steels, Inconel, and even Type 316 or 317 molybdenum containing stainless steel will be increased greatly if the surfaces are cleaned regularly and suitably to remove any occasional spots or deposits of iron or other impurities. If such impurities are left alone, the alloy may lose its passive nature in this area and corrode faster, causing pits in some alloys.

For mild cleaning of spots and deposits from the surface, it is good practice to employ fine pumice, finely bolted whiting or alkaline household cleansers containing similar material, rubbing, if possible, in the direction of the original surface grinding. If brushes are used, they should be of fiber. Steel wool should *never* be used. If the surface has become highly contaminated with iron rust, this can be removed with a 2-5% solution of warm oxalic acid followed by thorough washing. In cleaning, attention should be given to areas at joints, welds, or surfaces where impurities might collect or corrosion develop.

Stainless alloys such as the austenitic stainless steels and Inconel depend for their corrosion protection partly on the nature of the components themselves but principally on their property of possessing an invisible and ordinarily self-healing oxide film which imparts a passive state to the alloy. This passivating film is usually present but can become disturbed or impaired. The metal will then become active and corrode by being subjected to more than temporary contact with certain metals. These metals are notably iron and its compounds, certain chemicals or their solutions including appreciable concentrations of halogen salts such as chlorides, bromides, iodides, and also thiocyanates, particularly in neutral or acid solutions, and the corresponding halogen elements and acids, hydrochloric, etc., sulfuric acid more than 5%, contact with ordinary iron and steel, iron impurities (as from pipes) or iron (ferric or ferrous) compounds including ferricyanides, mercury salts including mercuric chloride, and sulfurous acid (water containing sulfur dioxide) under certain conditions. An exception to the latter is molybdenum containing stainless steels such as Types 316 and 317. Possible detrimental action of the compounds mentioned is also generally less with the Types 316 and 317 although the difference is one of degree, and long contact of most of the materials with even this alloy should be avoided. When any of the detrimental compounds have been in contact with the stainless alloys, they should be washed away thoroughly with water; the vessels should be

CONSTRUCTION MATERIALS FOR PROCESSING APPARATUS*

Solution	Storage Tanks	Pipe Lines	Racks and Hangers Sprockets and Idlers	Pumps Valves and Faucets	Coils
Developer	Wood (Cypress) Stainless Steel 316-317 Inconel Stainless Steel 304 Iron† (ungalvanized) Asphalt-coated wood Lead-lined wood Hard glazed stoneware Glass enameled steel Rubber-lined steel	Iron† (ungalvanized) Hard rubber Hard rubber-coated steel Stainless Steel 316-317 Inconel Stainless Steel 304 Nickel Glass	Stainless Steel 316-317 Inconel Stainless Steel 304 Hard rubber Bakelite impregnated fabric Nickel	Stainless Steel 316-317 Inconel Stainless Steel 304 Hard rubber Iron† Monel Nickel Glass (pumps)	Stainless Steel 316-317 Stainless Steel 304 Inconel Nickel Monel Lead
Acid fixing bath not containing silver	Lead Inconel‡ Stainless Steel 304‡ Otherwise same as for Acid fixing bath containing silver	Lead Inconel‡ Stainless Steel 304‡ Otherwise same as for Acid fixing bath containing silver	Inconel‡ Stainless Steel 304‡ Otherwise same as for Acid fixing bath containing silver	Inconel‡ Monel‡ Otherwise same as for Acid fixing bath containing silver	Stainless Steel 316-317 Inconel Monel Lead
Acid fixing bath containing silver	Wood (Cypress) Asphalt-coated wood Hard glazed stoneware Rubber-coated steel Glass enameled steel Stainless Steel 316-317	Hard rubber Soft rubber Rubber-coated steel Stainless Steel 316-317 Glass	Stainless Steel 316-317 Inconel‡ Stainless Steel 304‡ Hard rubber Bakelite impregnated fabric	Hard rubber Stainless Steel 316-317 Inconel‡ Glass (pumps)	Stainless Steel 316-317 Inconel‡
Water	Same as for Developer	Galvanized iron Otherwise same as for Developer	Stainless Steel 316-317 Hard rubber Inconel Bakelite impregnated fabric	Brass Hard rubber Stainless Steel 316-317 Inconel Monel	Stainless Steel 316-317 Inconel Monel Nickel
Distilled water	Block tin Aluminum (pure) Inconel	Block tin Aluminum (pure) Inconel Glass		Block tin Tin lined Inconel Aluminum (pure)	Block tin Tin lined or plated Aluminum (pure) Inconel

*Data for this table were compiled from actual experience of the authors and from information supplied by R. M. Corbin, C. E. Ives, R. S. Scott, J. Folwell, and others to whom the authors are indebted.

†With reservations. See pages 8 and 28.

‡NOTE: These materials become pitted under certain conditions of use especially with acid fixing baths when the vapors of sulfur dioxide are confined within the apparatus. Of the commercially available alloys, Stainless Steel Type 317 is considered to be the most resistant with Type 316 closely analogous. Inconel and 18-8 Stainless Steel with carbon 0.08 max. (Type 304) as clad materials when properly welded are recommended with the same reservations as for the corresponding solid alloys.

refilled with other solution or water or drained and dried so as to prevent the drying of residual salts on the surfaces.

Wrought iron developer supply pipes should be kept filled with solution. If flushed out with water, they should be refilled immediately with developer, otherwise the water (containing oxygen) will attack the metal, rapidly forming much brown oxide and hydroxide of iron.

PRECAUTIONS TO BE TAKEN WHEN SELECTING CONSTRUCTION MATERIALS

1. Do not permit tin, copper, or alloys containing these metals to come in contact with developing solutions, especially concentrated developers, because more or less of the tin or copper will dissolve and cause either serious chemical fog or rapid oxidation of the developer. Do not use galvanized iron vessels to mix developing solutions containing sodium bisulfite because sodium hydrosulfite will be formed, which is a bad fogging agent. Likewise, the zinc in the inner coating of galvanized piping will cause developer fog.

Contact of two or more different metals or alloys exposed to a developer will hasten the rate of corrosion and thus increase the resultant fog. Soldered joints are to be avoided with developers, but if unavoidable, a low-tin or tin-free solder should be used, and the joints made to expose a minimum of solder to the solution.

2. Maximum corrosion resistance to developers and acid fixing baths with stainless steel will be secured by using an 18-8 type containing 2-4% molybdenum such as Type 316 or 317.[45] When maximum resistance is not required or when special fabrication is needed, other types of 18-8 stainless steel can be chosen in accordance with the individual conditions of the problem. Stainless steels with low carbon content (0.08 max.) can be used for the construction of equipment subjected only to intermittent service such as trays, hangers, etc., that will be exposed to acid fixing baths. Joints should be welded and heat treated, if necessary, according to the manufacturer's instructions. Occlusions should be ground away from the back of the weld. The use of steels containing columbium is claimed to decrease corrosion by preventing segregation of carbon near the weld.

3. For most acid oxidizing solutions and acid, neutral, and acid oxidizing solutions containing chlorides, bromides, iodides, thiocyanates, ferricyanides, iron or mercuric compounds, the use of metals should be avoided unless specifically resisting materials are proved in tests by the user.

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[45] Stainless steel should not be used with solutions containing hydrochloric acid or potassium ferricyanide.

4. In many cases the use of metals for trays, linings, small apparatus, tanks, and other equipment can be avoided by using suitable thermoplastic artificial resin materials. Trays lined with pure gum rubber sheeting or paraffined cloth can be used for solutions that attack metals.

5. For toning purposes the passive stainless alloys, particularly the more resistant varieties, have been used successfully for intermittent service with proper cleaning and care of the equipment.

6. When metals are chosen for the construction of apparatus, a single metal should be used whenever possible, and it should be either electrowelded or soldered from the outside to avoid electrolytic corrosion. Seams in containers made of sheet lead should be joined together by lead burning.

7. Apparatus constructed of aluminum, zinc, or galvanized iron should not be used with either developers or fixing baths since these metals react with such solutions with the formation of precipitates which leave a deposit on the film and often stain the gelatin. A galvanized iron or zinc wash tank in continuous use usually corrodes rapidly due to the action of the silver salts carried over by the film or prints from the acid fixing bath.

8. Plated metals should be avoided whenever possible for use with photographic solutions and only single metals or alloys used, since electrolytic corrosion sets in as soon as a little of the plating wears off.

9. For fixing baths or strong saline solutions, avoid porous materials such as incompletely glazed earthenware, impregnated fibrous materials, or rubber compositions containing large proportions of mineral filler, because crystallization of the salts within the pores of the materials causes disintegration.

10. Trays or tanks coated with lacquer or baked japan are not resistant to strongly alkaline developers or fixing baths of high acid concentration.

11. Avoid the use of cheap rubber tubing or other materials containing free sulfur, metallic sulfides, or polysulfides in connection with developing solutions, because the alkali in the developer attacks these and forms alkaline sulfides which cause chemical fog. Some types of soft rubber sheeting cause a flocculent precipitate to form in developers. Such sheeting is unsatisfactory for use with developers but usually can be used with fixing baths.

12. Corrosion of stainless steels and other alloys will be minimized greatly if the surface of the alloy is cleaned at regular intervals.

NOTES ON WELDING STAINLESS STEEL TANKS[46]

In constructing tanks from corrosion-resisting materials such as the Stainless Steels, Types 304 and 316, it is important that the material be furnished with a low carbon content. It is essential that the carbon content be 0.08% or less in order to inhibit the intergranular corrosion which occurs at the joints of welded seams due to deposition of excess carbides when the welding heat is applied. It has been found that with a carbon content of 0.08% or under, this characteristic will be controlled and there will be practically no excess carbides deposited along the grain boundaries.

For tanks which are large enough to hold 50 to 100 gallons, stainless steel sheets of at least 16 gauge thickness should be used. Where possible, corner welds should be avoided, particularly if the sheets on the inside of the tank are to be polished. In other words, the bottoms and sides should be so formed that the joints will come one inch or so from the corners so that the seams will be easier to grind and a straight butt type of seam can be welded. Stainless steel sheets should be annealed fully, and where the tanks are to be cleaned easily, they should have at least a No. 2-B finish.

There are four commonly accepted methods of welding stainless steel in commercial use today. These are as follows:

1. Oxyacetylene method	Use Uncoated Electrodes
2. Carbon Arc (electric method)	
3. Atomic Hydrogen Arc	
4. Metallic Arc	Use Coated Electrodes

The first two methods are not recommended since there is danger of carbon pickup in the welded seam by the use of either the oxyacetylene or carbon arc method. For this reason where the full corrosion-resistant value of the 18-8, and 18-8 molybdenum stainless steel is to be realized, the third or fourth method is recommended. The use of the atomic hydrogen arc with uncoated electrode results in a very flat seam with a minimum of distortion and, on the whole, with very good results. It will be found, however, that there are comparatively few skilled operators for the atomic hydrogen arc welding method. For this reason it probably will not be available in many locations.

The metallic arc method makes use of the ordinary commercial electric arc welding machines. It is well to specify the use of electrodes or welding wire which will have the same approximate analysis as the sheets themselves, in other words, the same A.I.S.I. type numbers, that is 18% chrome, 8% nickel, 3% molybdenum. The electrodes should be coated so that full advantage can be taken of the protective gas which is released by the use of this type of electrode, resulting in a more ductile weld due to the protection from the rapid oxidation of the deposited weld metal. Reversed polarity should be used with all types of metallic arc welding of stainless steel, that is, the work or tank sheet should be the negative terminal and the electrode the positive one. The coefficient of expansion of austenitic stainless steels such as 18-8 alloys is approximately 50% greater than mild steel. For this reason, in setting up the job for welding due allowance should be made for expansion and contraction. That is, greater care should be taken to use proper welding fixtures and clamps to prevent localized strains and distortion of the tank.

After the weld has been made, it will be noticed that there is a discoloration along the sides of the weld seam. This is due to the scale which is formed at the high temperature of the welding arc. This scale and excess weld metal should be removed by grinding.

While the welding of the corrosion-resistant austenitic stainless steel materials is not difficult, a proper technique must be developed for use with equipment at hand (or available). This can well be undertaken with the cooperation of the manufacturer of welding electrodes.

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[46] The authors are indebted to the Engineering and Maintenance Shops of the Kodak Park Works for the data supplied in this section.